

An aerial photograph of Paris, France, showing the city's dense urban landscape and the Seine river winding through it. The sky is clear and blue, and the city extends to the horizon. The text is overlaid on the top half of the image.

# **Air-quality forecasting: Needs for research from a European perspective**

**Adrian Simmons**

**European Centre for Medium-Range Weather Forecasts  
and MACC Consortium**

# GMES atmospheric environmental services

- **A component of Europe's Global Monitoring for Environment and Security initiative**

- which also provides services for land and ocean



- **The atmospheric programme comprises**

- developing operational space-based observation of constituents
- strengthening the provision of complementary *in-situ* observations
- developing and operating associated data and information services

- **A 48-partner EC-funded project called MACC**

- provides core monitoring and forecasting services
- will support downstream services for specific sectors
- is coordinated by ECMWF



# The GMES Sentinel satellite missions/instruments



**Sentinel 1**

**Land and ocean**

**Launches from 2011**



**Sentinel 2**

**Land**

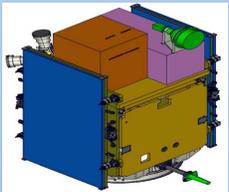
**Launches from 2012**



**Sentinel 3**

**Land, ocean and some atmosphere**

**Launches from 2012**



**Sentinel 5 precursor**

**Atmosphere  
(UV/VIS/NIR/SWIR - Polar)**

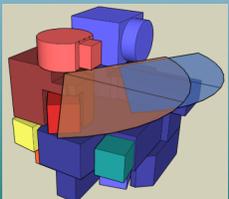
**Launch 2014**



**Sentinel 4  
on MTG-S**

**Atmosphere  
(UV/VIS/NIR - Geostationary)**

**Launches from 2017**



**Sentinel 5  
on post-EPS**

**Atmosphere  
(UV/VIS/NIR/SWIR - Polar)**

**Launches from 2020**

# **GMES atmospheric environmental services**

**Services related to the chemical and particulate content of the atmosphere, providing data and information on:**

- Climate forcing by greenhouse gases and aerosols**
- Long-range pollutant transport**
- European air quality**
- Dust outbreaks**
- Resources for solar power generation**
- Stratospheric ozone and UV radiation**
- ...**

**through global and regional processing based on adapting the data assimilation and forecasting approaches of numerical weather prediction**

# MACC succeeds GEMS and PROMOTE projects

**PROMOTE**  
Protocol Monitoring for the GEMS Service Element: Atmosphere

Project supported by the European Space Agency  
Stage 2 - Up-scaling the GSE Atmospheric Monitoring portfolio  
July 2006 - August 2009

**Mission**  
To deliver the Atmosphere GEMS Service Element a sustainable and reliable on the atmospheric policy issues of stratospheric ozone depletion, surface UV

**Services**  
Ozone Service    UV Service    Air Quality Service

**Services by user communities**  
Health    Meteorological    Environmental    Research/M

esa    gmes SERVICES  
GEMS, Global Monitoring for the European Community

April 2004 – Dec 2009

**GEMS Project at ECMWF - GEMS GCP IGOS**

**Project Objectives**  
The EU-funded GEMS project is developing comprehensive data analysis and modelling systems for monitoring the global distributions of atmospheric constituents important for air quality and UV radiation, with a focus on Europe.

**Products**  
Reanalysis    Regional Air Quality    Aerosol Forecast    UV Forecast  
Reactive-gas Forecast    POLARCAT Support    Greenhouse Gases

**Themes**  
• Overview  
• Global Greenhouse Gases  
• Global Reactive Gases  
• Aerosols  
• Regional Air Quality  
• Production  
• Validation

**Project Information**  
• About the Project  
• Participants List  
• Documents  
• Meetings, Workshops & Seminars  
• Software & Tools  
• Products  
• Data Access (new)  
• Collaboration Tools  
• Reporting Tools  
• Contact Us

First versions of the systems are now being run daily to provide current analyses and retrospective analyses for the years 2003-2007. Prototype products are available for inspection, trial use and user feedback. Products are at present openly available in graphical form. Provision of digital data is under development.

March 2005 – May 2009

www.gmes-atmosphere.eu

**MACC Project - Home**

Monitoring atmospheric composition & climate

**mac** Monitoring atmospheric composition & climate

**Home**  
MACC (Monitoring Atmospheric Composition and Climate) operates and improves data-analysis and modelling systems for a range of atmospheric constituents that are important for climate, air quality and surface solar radiation. Product lines include data records on atmospheric composition for recent years, data for monitoring present conditions and forecasts of the distribution of key constituents for a few days ahead.

**Featured products**  
Global Forecasts    European Air Quality Forecasts    HIPPO Campaign Support    GEMS Reanalysis

MACC is a Collaborative Project (2009-2011) funded by the European Community under the 7th Framework Programme. It is coordinated by the European Centre for Medium-Range Weather Forecasts and operated by a 45-member consortium.

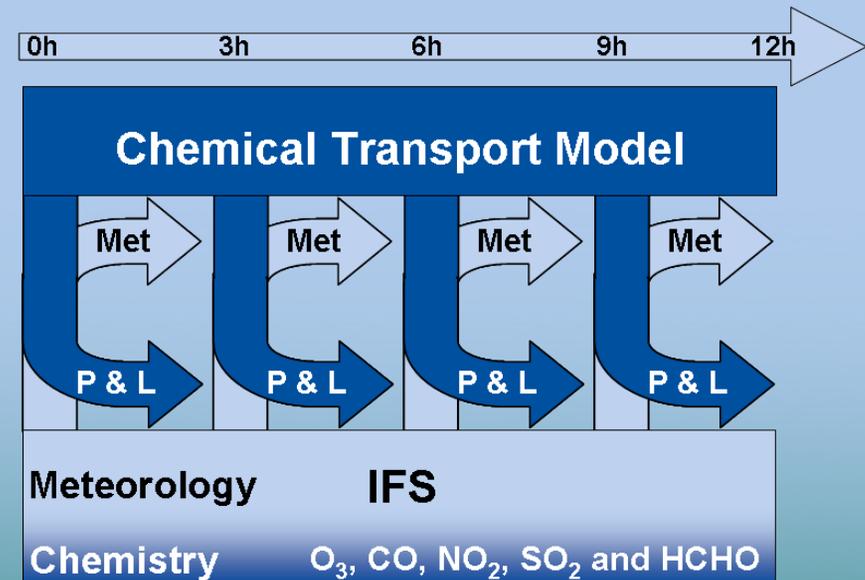
June 2009 – ????

# GEMS/MACC global data assimilation system

- **Based on ECMWF's "Integrated Forecasting System" - IFS**
- **CO<sub>2</sub>, CH<sub>4</sub> and aerosols have been incorporated in the IFS** and data assimilation has been developed for AIRS and IASI radiances, SCIAMACHY retrievals, MODIS aerosol optical depth, ... GOSAT ...
- **IFS also carries O<sub>3</sub>, CO, NO<sub>2</sub>, SO<sub>2</sub> and HCHO**

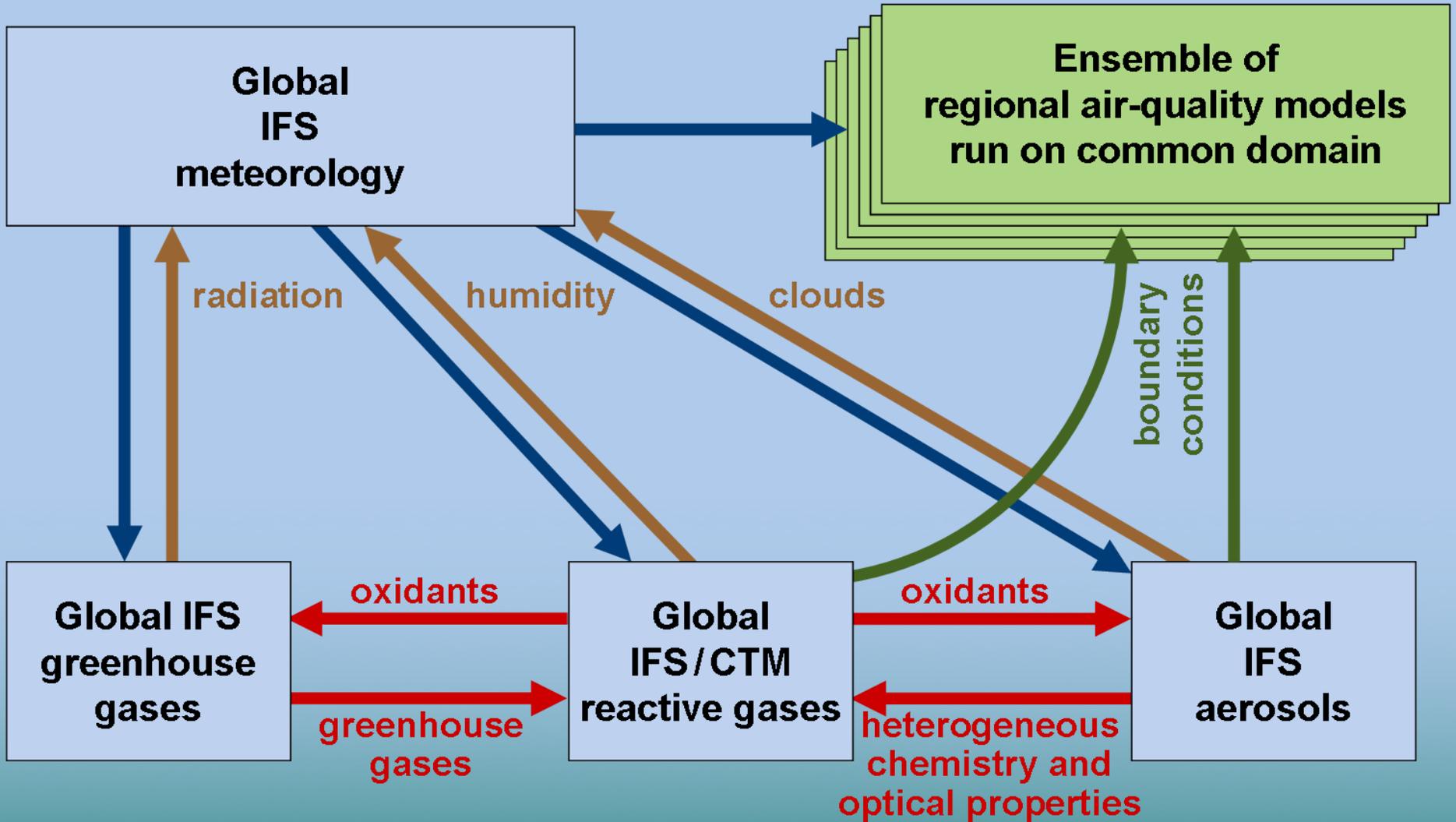
Chemical production and loss come from a coupled CTM, either MOCAGE, MOZART or TM5

Data for assimilation come from GOME, GOME-2, IASI, MIPAS, MLS, MOPITT, OMI, SBUV/2, SCIAMACHY, ...

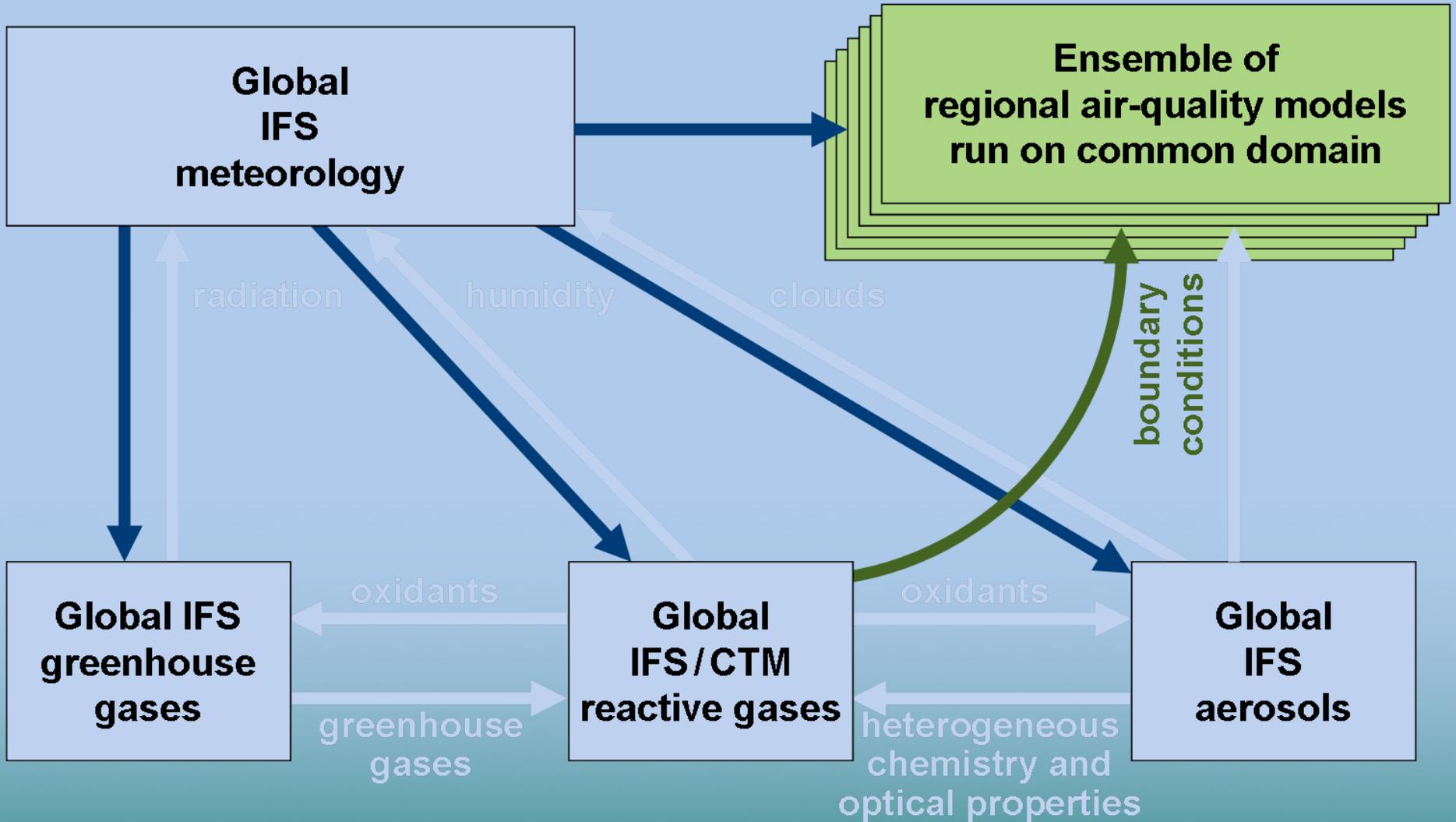


- **Chemistry modules are being built fully into IFS**

# Global/regional system



# Global/regional system



**GEMS “climatologies” of CO<sub>2</sub>, CH<sub>4</sub> and O<sub>3</sub> used in radiation parameterization in latest version of operational ECMWF system**

# What about emissions?



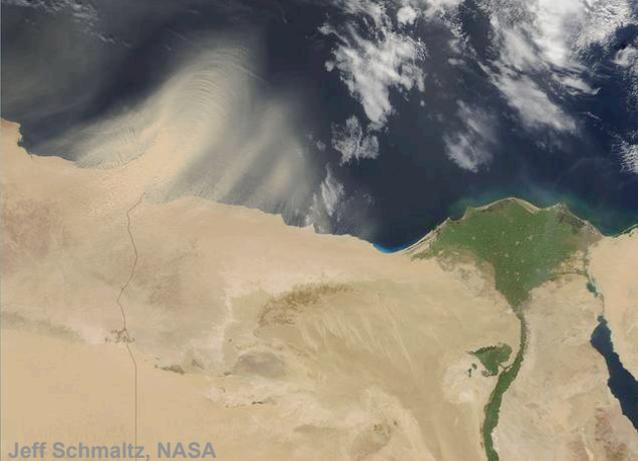
USGS



© Peter Facey



© Peter Kaminski



Jeff Schmaltz, NASA

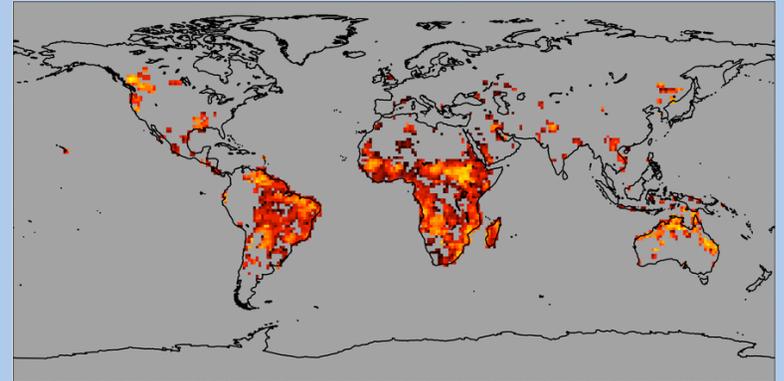


© Brent Buffington

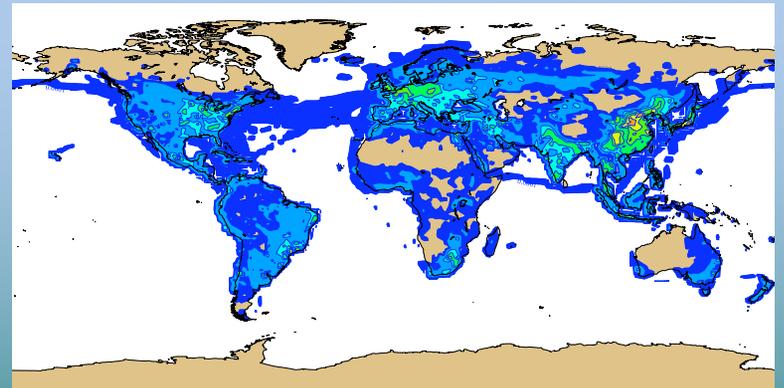
# Sources and sinks

- **Near-real-time fire analysis**
  - based on SEVIRI and MODIS data
- **Parameterized dust and sea-salt**
- **Vegetation model for fluxes of ...**
  - need for better links with meteorology
- **Inventory-based emission estimates**
  - need for resolution and timeliness
- **Application of flux-inversion for net source-sink corrections**
  - working for CO<sub>2</sub> and CH<sub>4</sub>
  - under development for aerosols
  - under consideration for reactive gases

Fire radiative power: 12 November 2009



Black carbon: fossil-fuel source

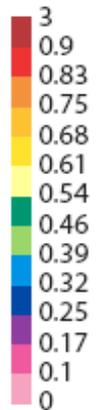
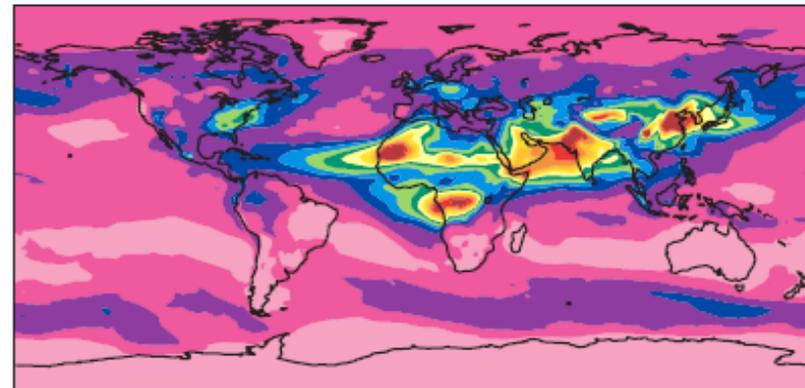
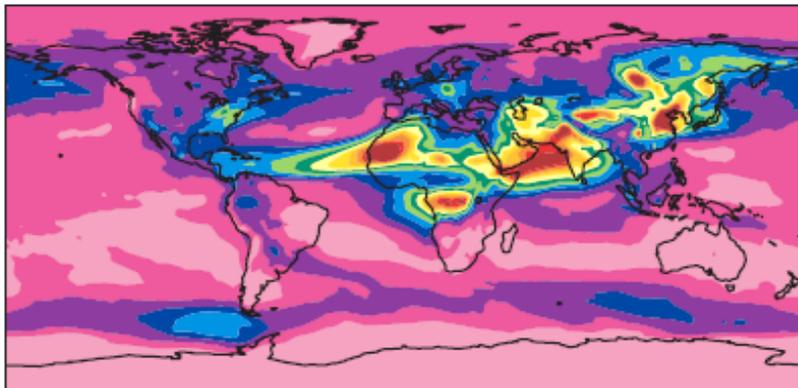
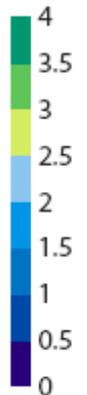
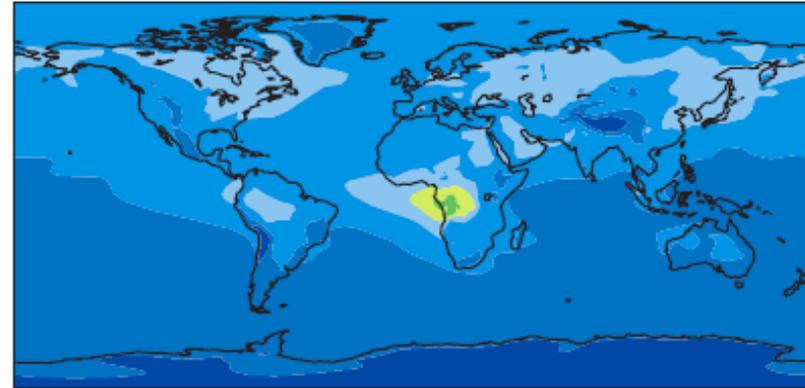
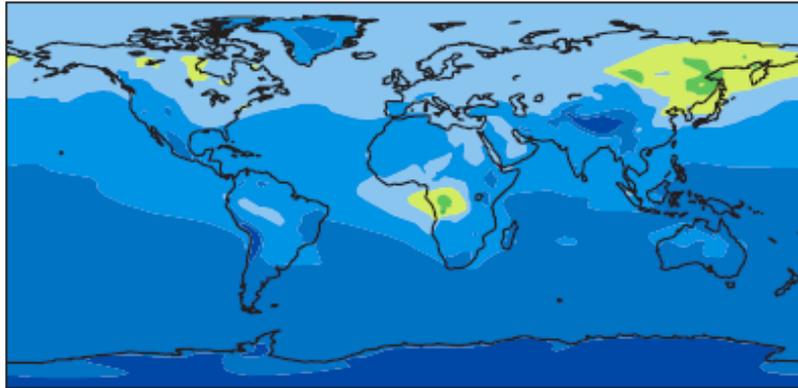


# From GEMS/MACC retrospective analysis 2003-2009

July 2003

Total column carbon monoxide

July 2005



July 2003

Aerosol optical depth at 550nm

July 2005

**MACC will produce a new global reanalysis for 2003-2010  
and regional reanalysis for 2007-2009**

# Real-time aerosol forecasts

NewsRadio Now playing

ABC News

Video

News Home Just In Australia World Business Entertainment Weather

## DUST STORM

Video, your pics and comments

Print Email Share Add to My Stories

## Dept admits error in air quality forecast

Posted 11 hours 54 minutes ago

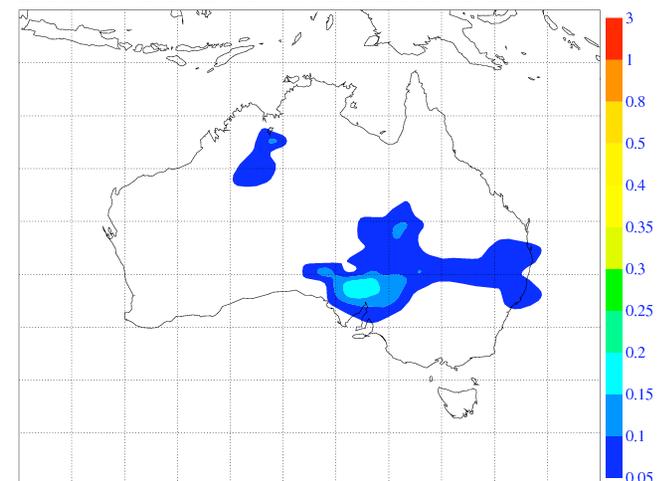
Updated 11 hours 51 minutes ago

The New South Wales Environment Department has admitted its forecast for air quality in Sydney today was wildly wrong after a dust storm prompted hundreds of emergency calls due to breathing difficulties.

Audio: Respiratory expert Dr Christine Jenkins speaks to ABC Local Radio (ABC News)

Until this morning, the department's website was forecasting conditions would be good.

20090921 00UTC FC t+3 valid at 03UTC 20090921



MACC dust aerosol optical depth

BBC

Low graphics Help

NEWS

LIVE BBC NEWS CHANNEL

News Front Page

Page last updated at 10:42 GMT, Wednesday, 23 September

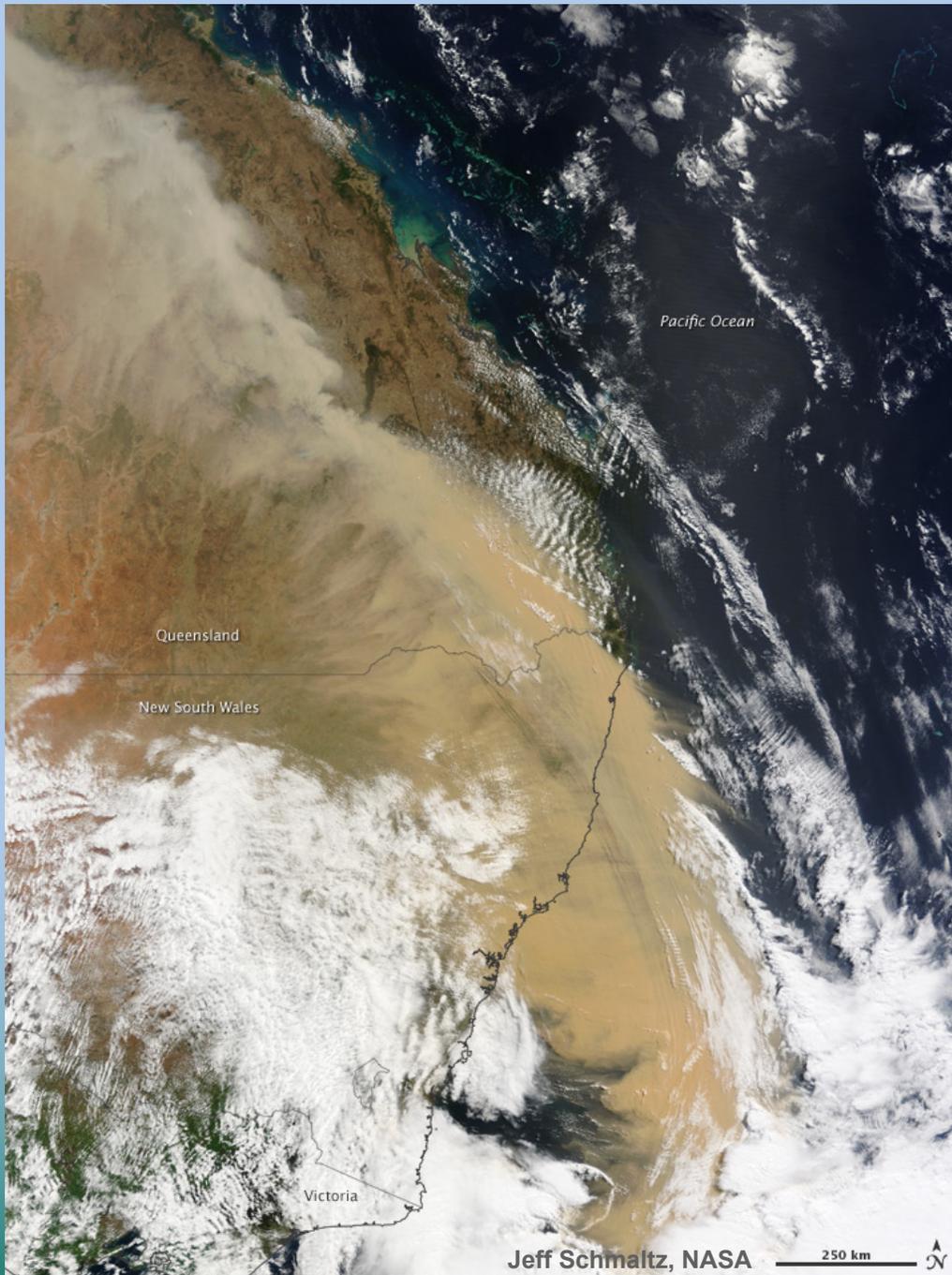
## Desert dust storm chokes Sydney



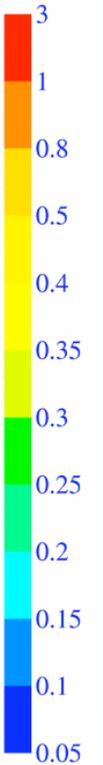
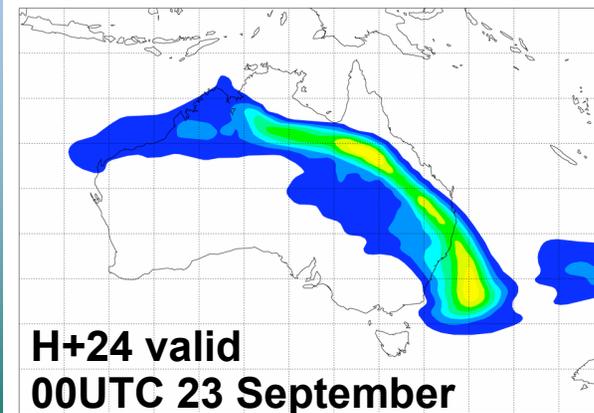
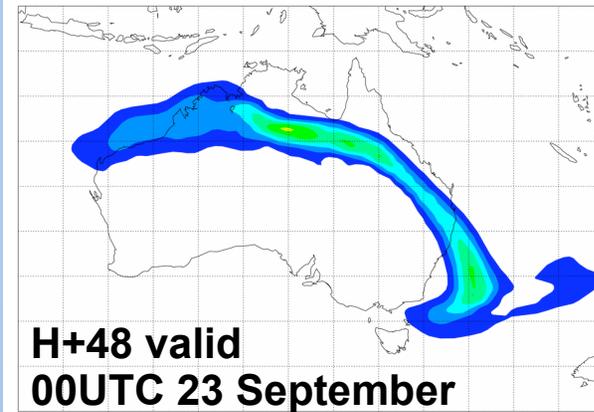
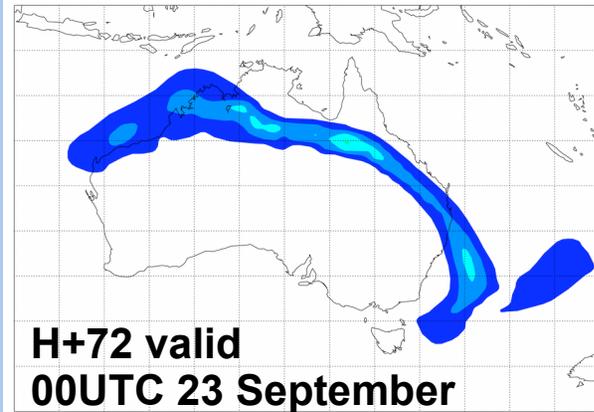
Sydney's red dust has been blown from the outback

A large stretch of Australia's east coast, including the largest city Sydney, has been shrouded in red dust blown in from the desert outback.

Visibility in Sydney was so bad that flights were diverted and harbour ferry traffic disrupted.



## Dust aerosol optical depth

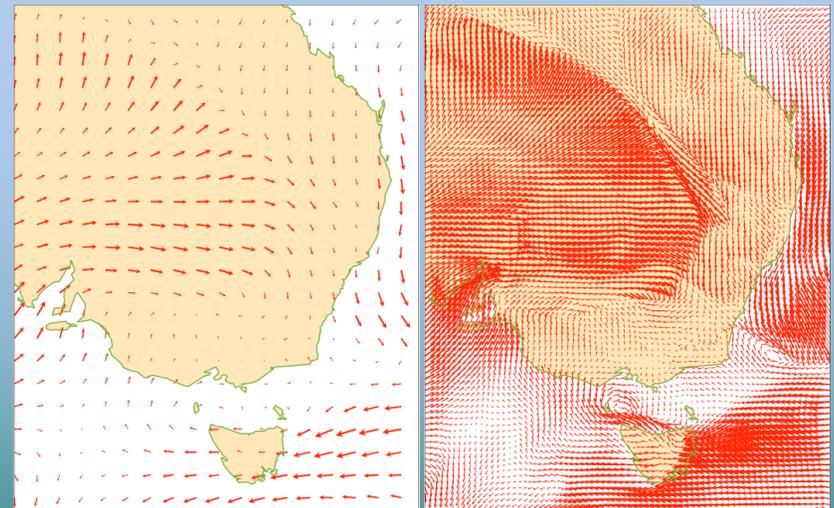


## Some considerations

- **Dust-band is consistently positioned in successive forecasts**
  - basic meteorology has been captured reasonably well
- **Intensity increases as forecast range decreases**
  - underestimation of dust in the background forecast is corrected by assimilating MODIS (or other) data
- **Possible factors**
  - parameterization of dust mobilization
  - resolution of global system
  - soil moisture analysis
  - aerosol retrieval over bright surfaces



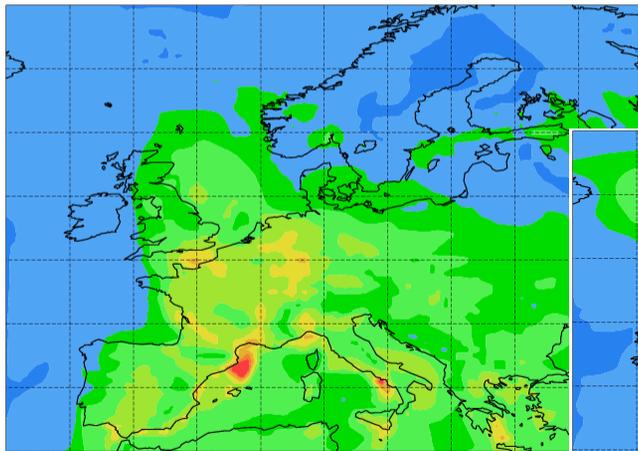
10m wind analysis for  
12UTC 22 September 2009



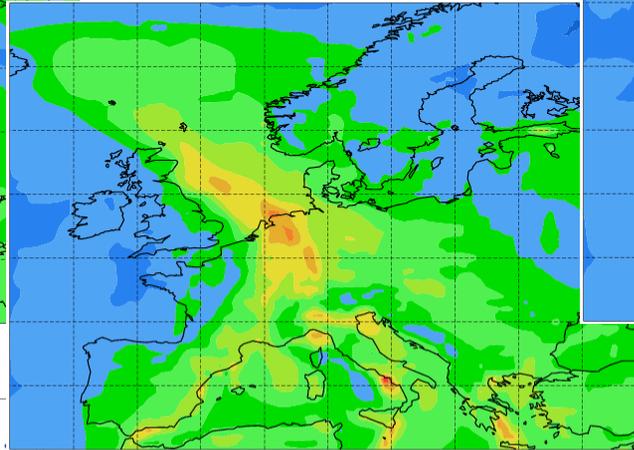
MACC  
T159 (~125 km)

Pre-operations  
T1279 (~16 km)

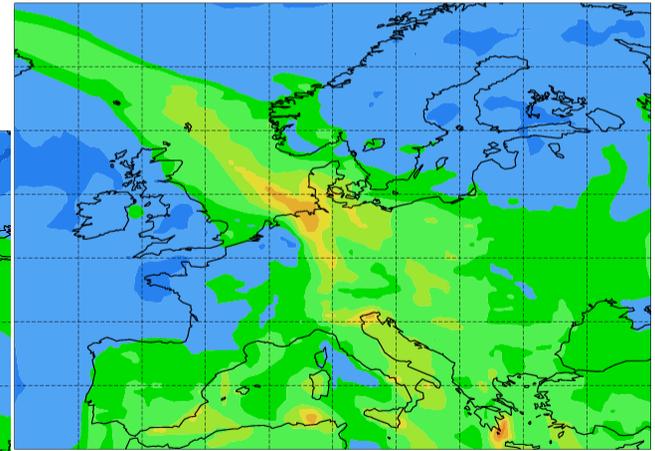
# Regional air quality: successive 63h surface ozone forecasts from CHIMERE and verifying observations



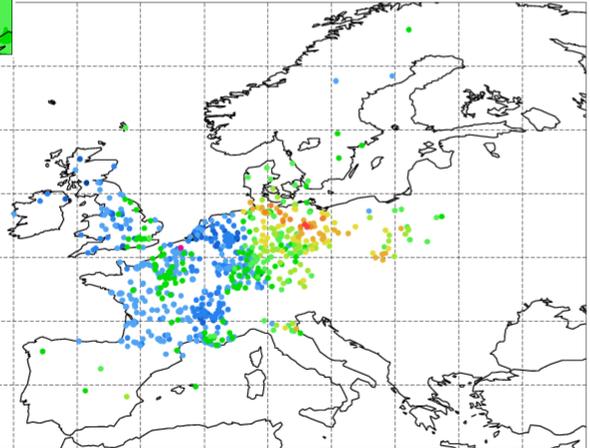
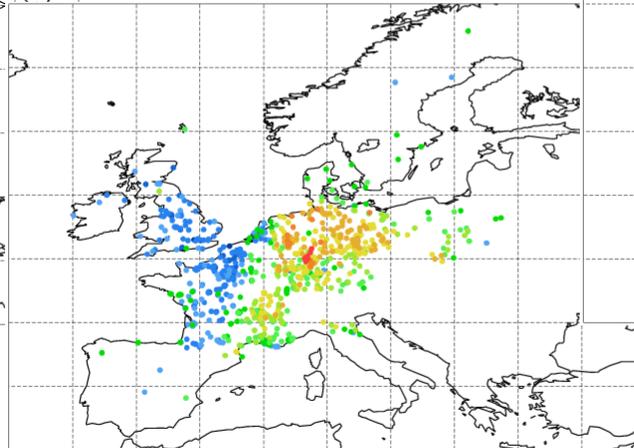
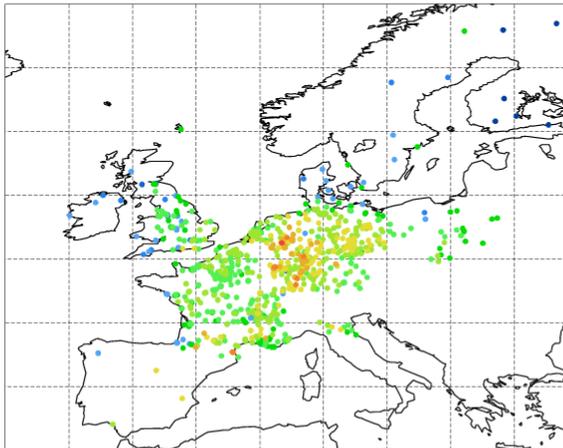
15UTC 1 July 2008



15UTC 2 July 2008

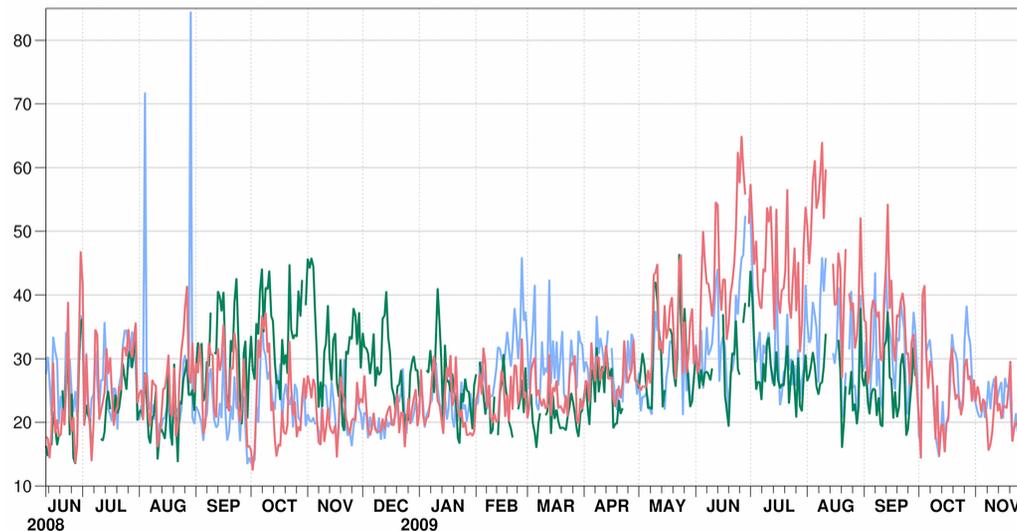
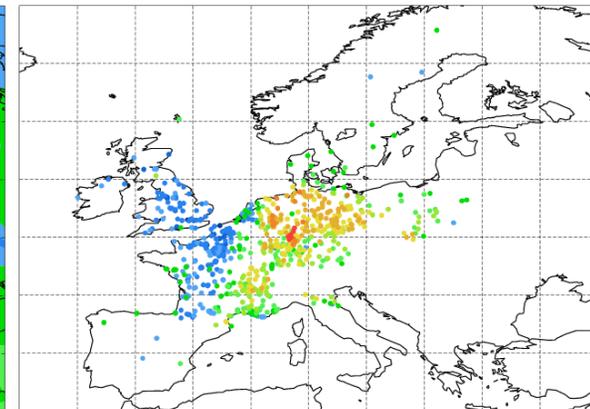
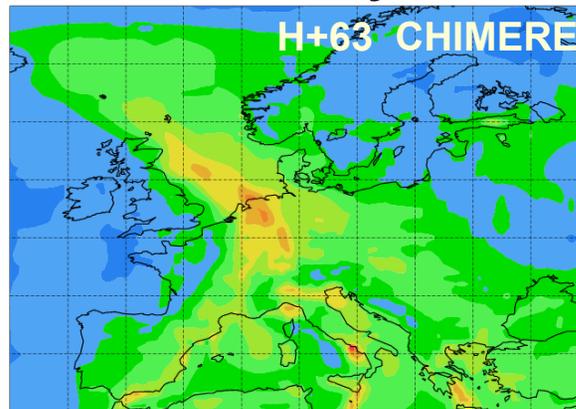
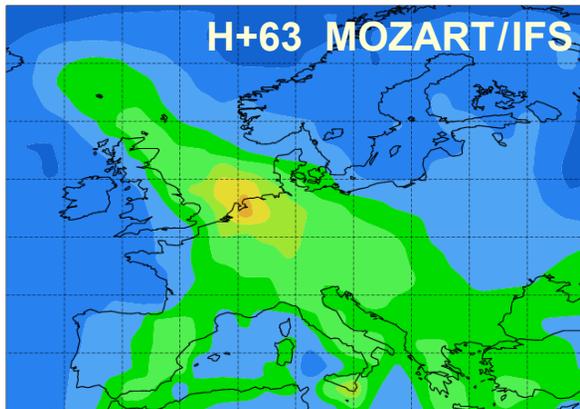


15UTC 3 July 2008



# Regional air quality: comparison of MOZART/IFS and regional forecasts

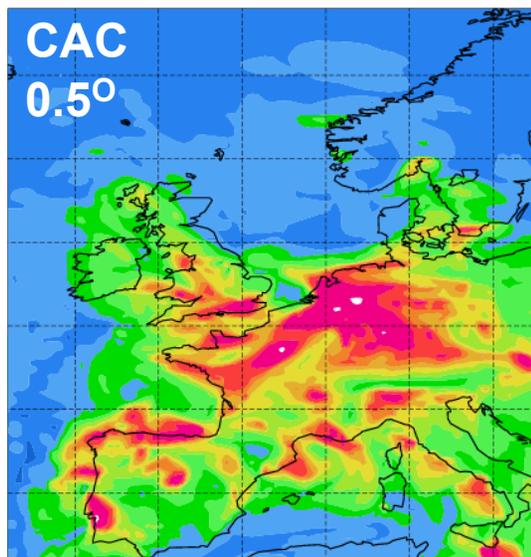
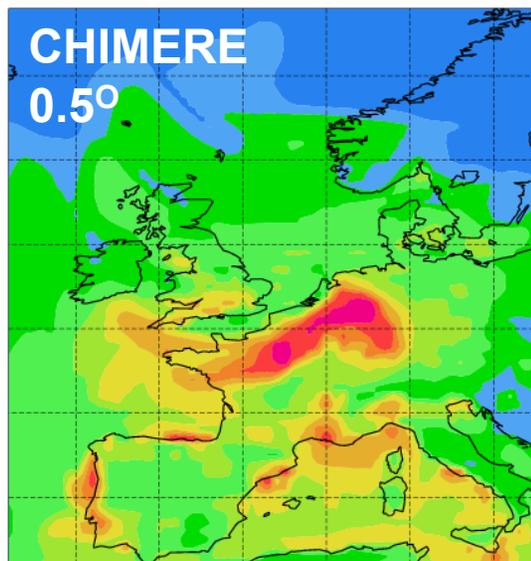
15UTC 2 July 2008



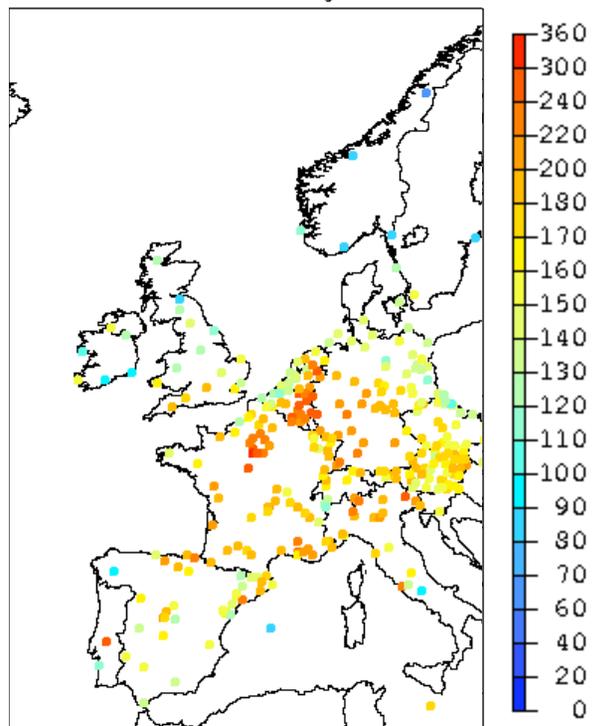
GEMS/MACC RAQ Verification  
Surface Ozone [  $\mu\text{g}/\text{m}^3$  ]  
Root mean square error forecast  
Europe  
T+63 00UTC

- EURAD-IM
- CHIMERE
- MOZART/IFS

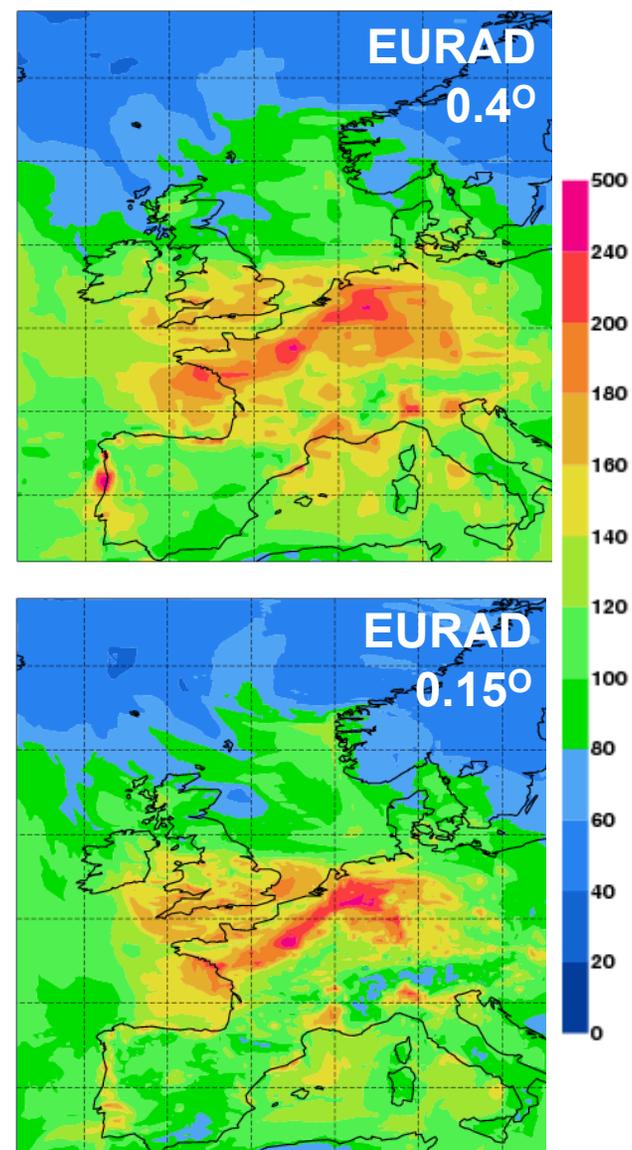
# Retrospective case study: 8 August 2003



**PREV AIR** Airbase Ozone for 20030808: 1389 stations  
354 Background Rural Stations

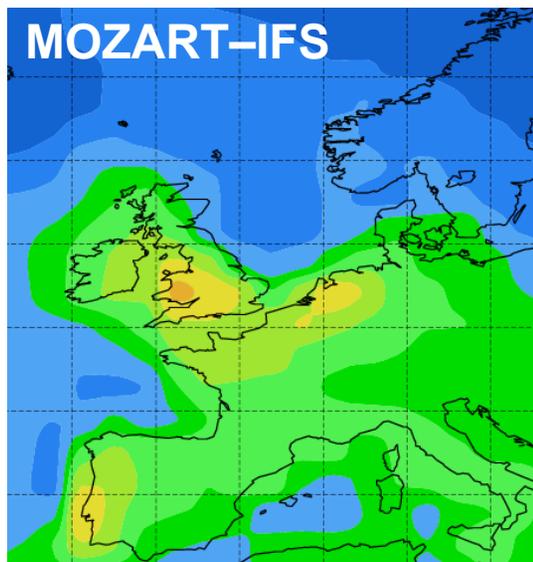
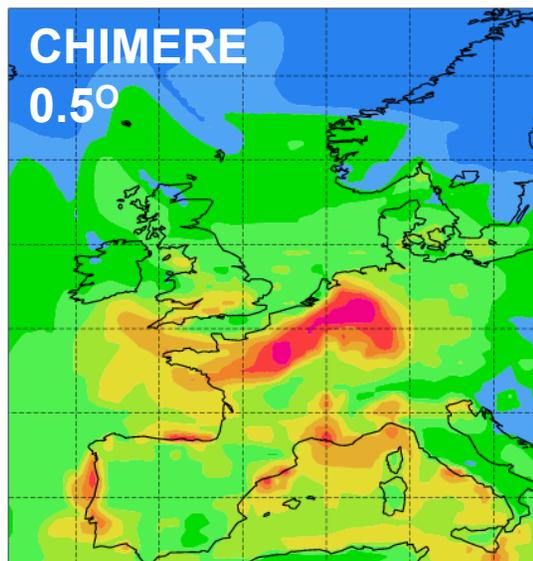


Airbase Ozone le 20030808: 1389 stations  
354 stations Fond Rural

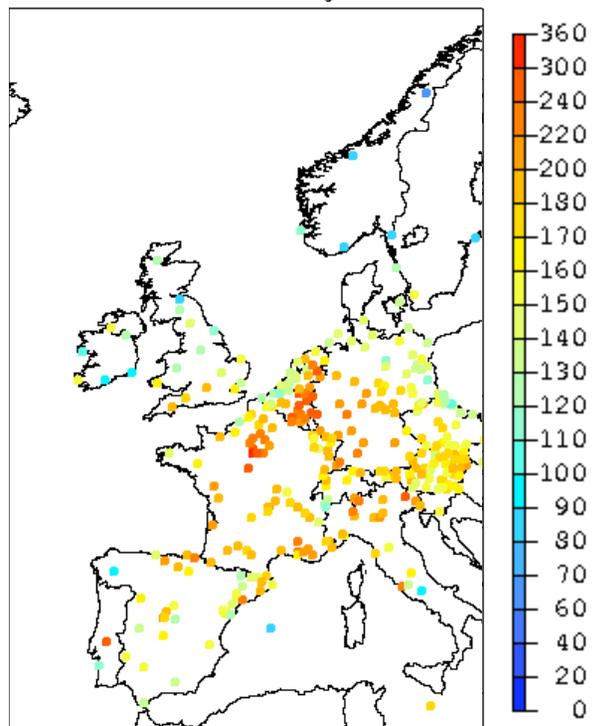


Maximum ozone ( $\mu\text{g}/\text{m}^3$ )

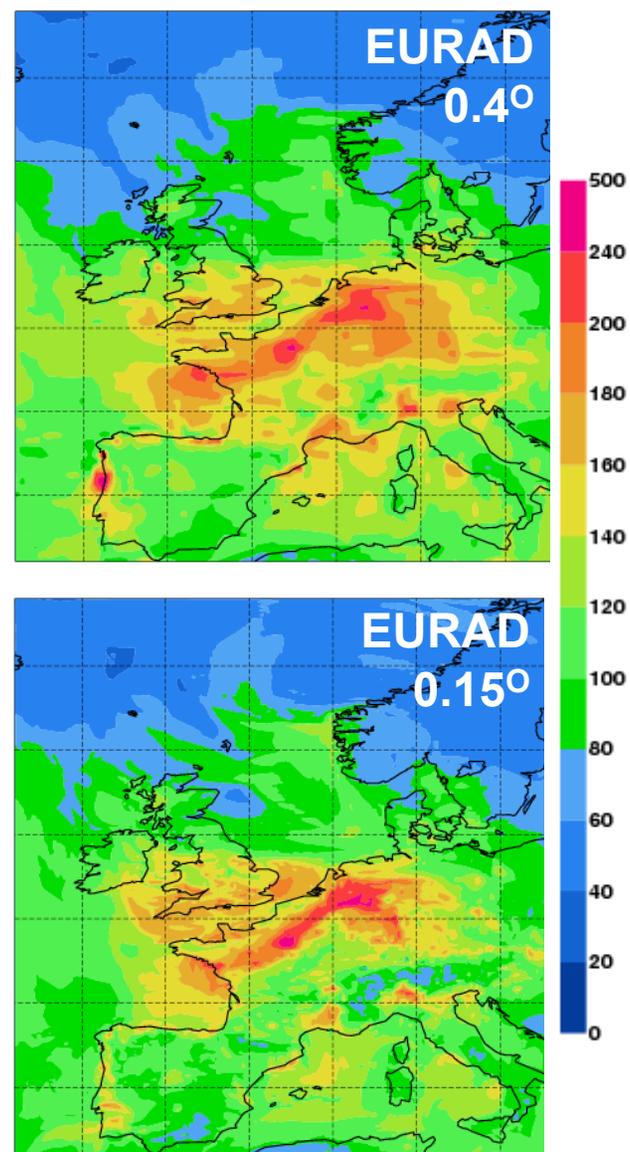
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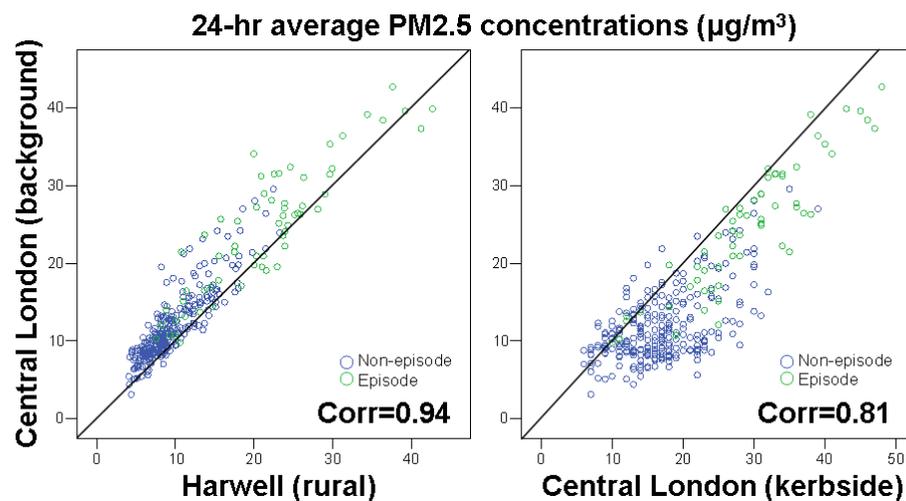
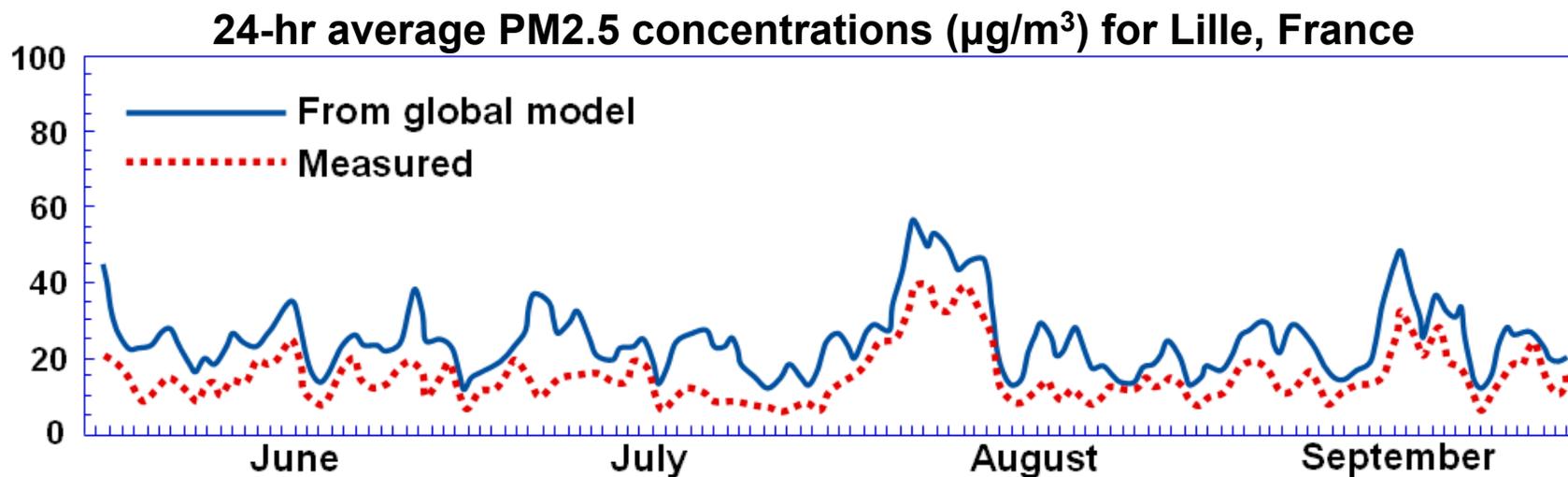


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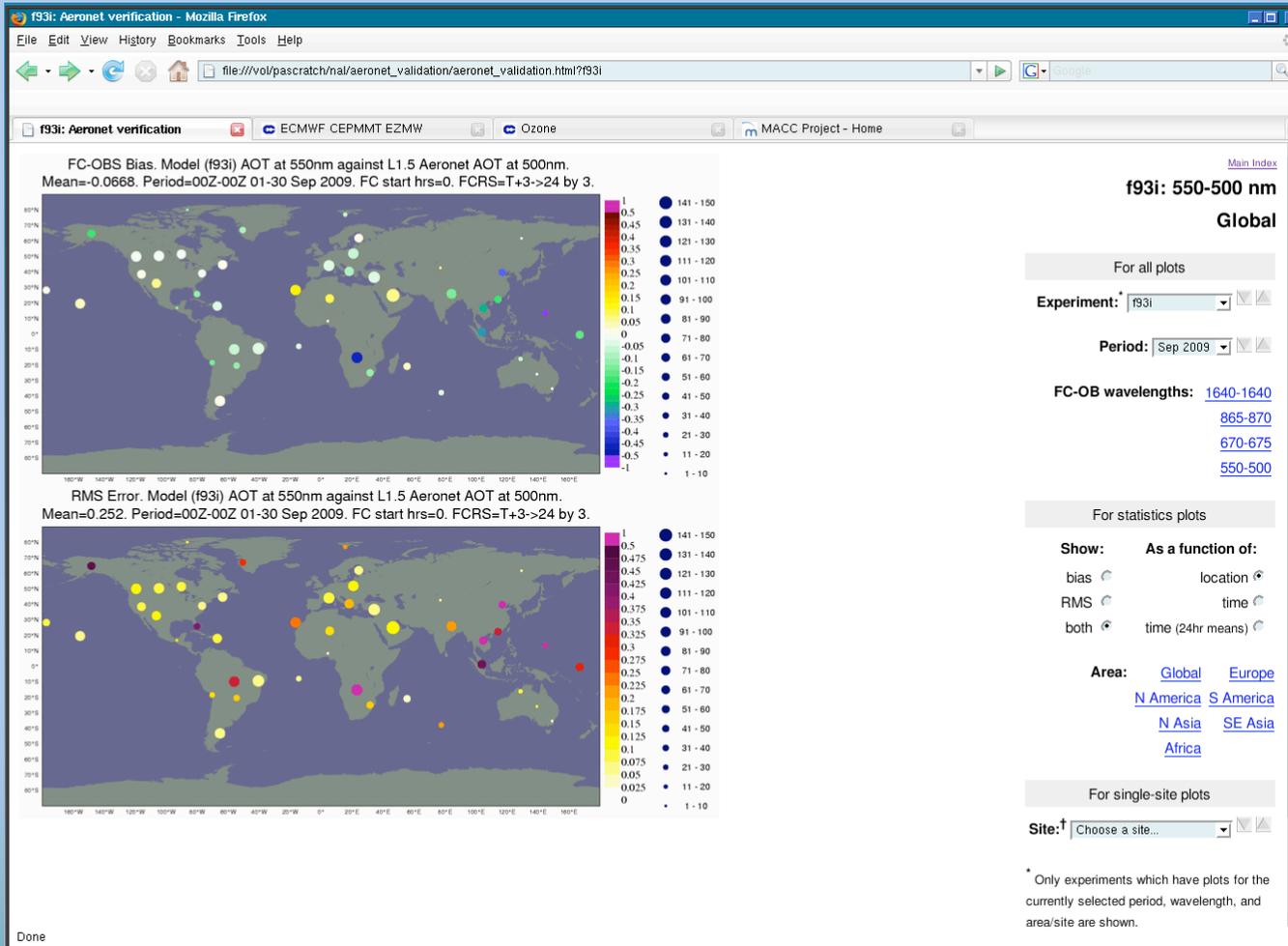


Maximum ozone ( $\mu\text{g}/\text{m}^3$ )

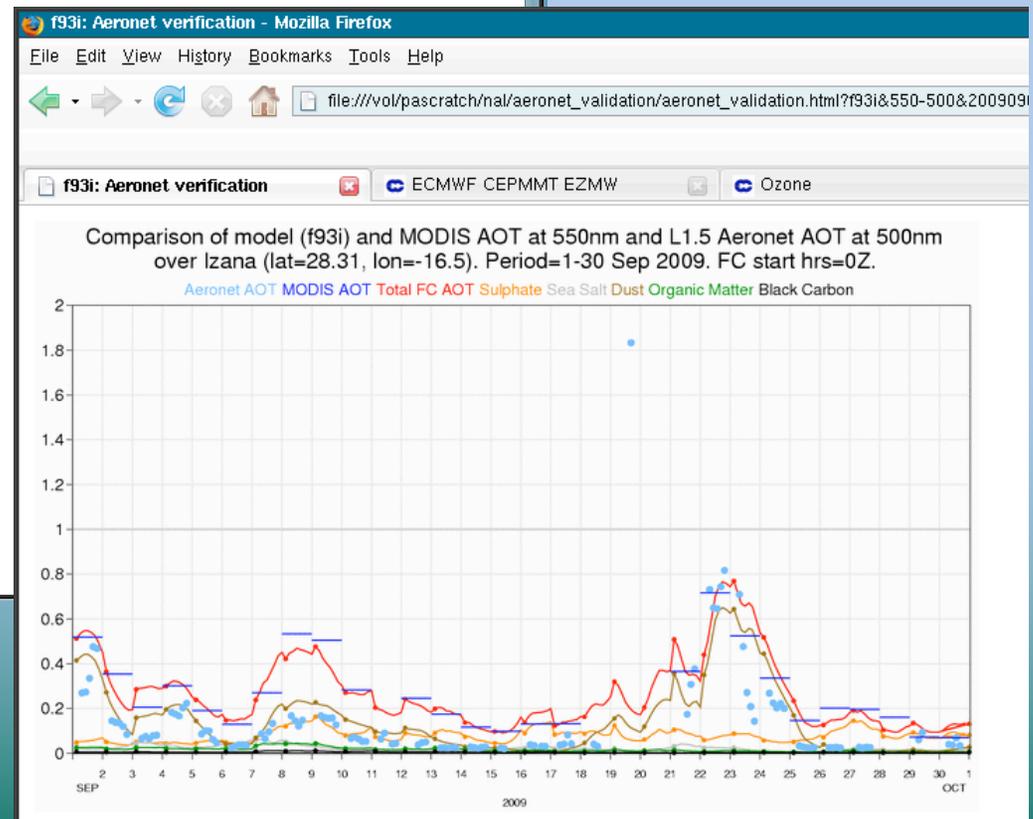
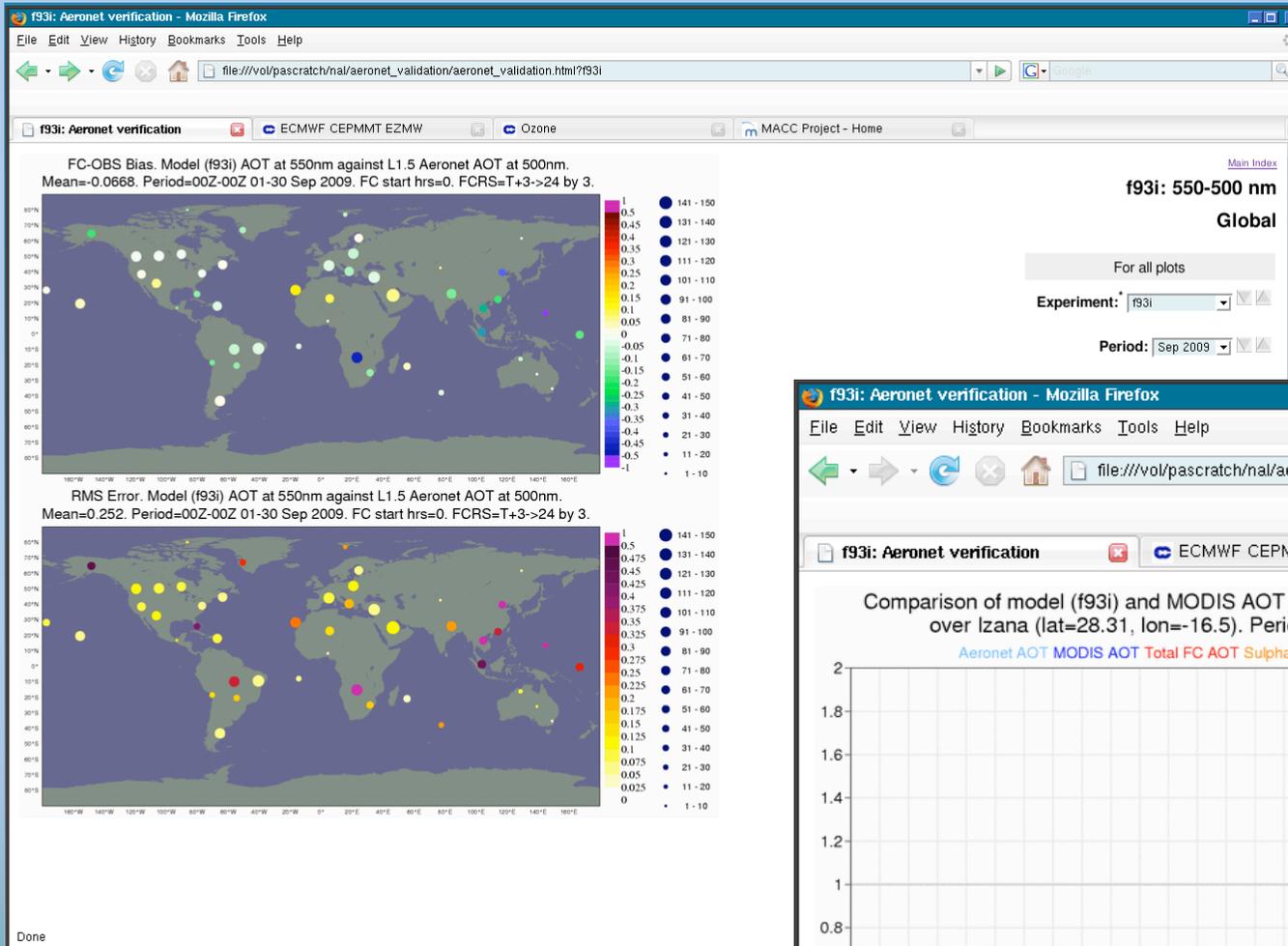
# August 2003 heat-wave (from 2003-2009 reanalysis)



# Validation against AERONET data



# Validation against AERONET data

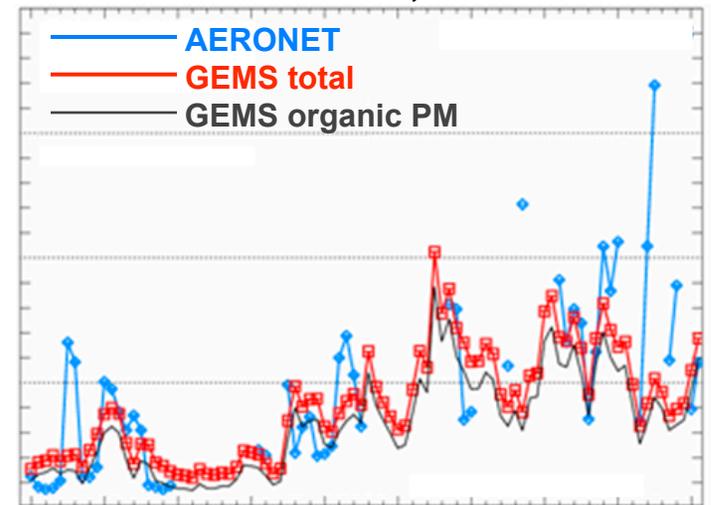
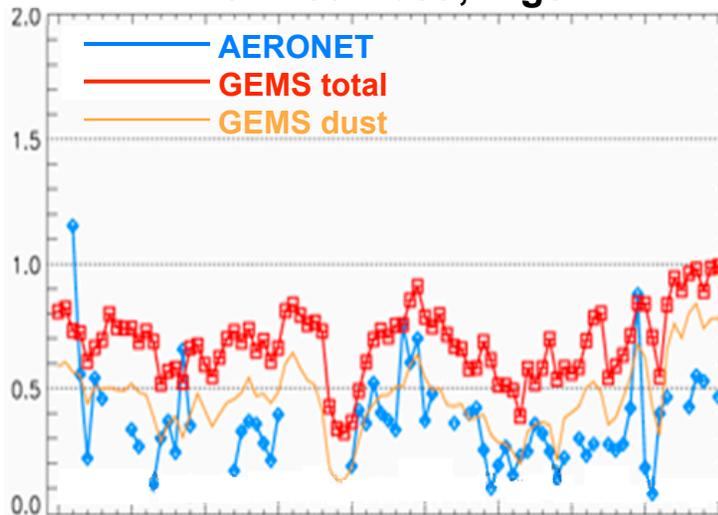


# Validation against AERONET data

Site dominated by dust  
Banizoumbou, Niger

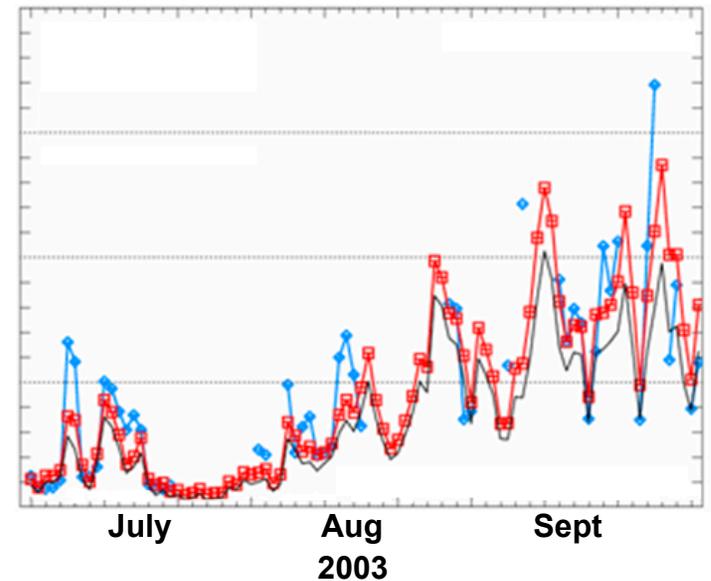
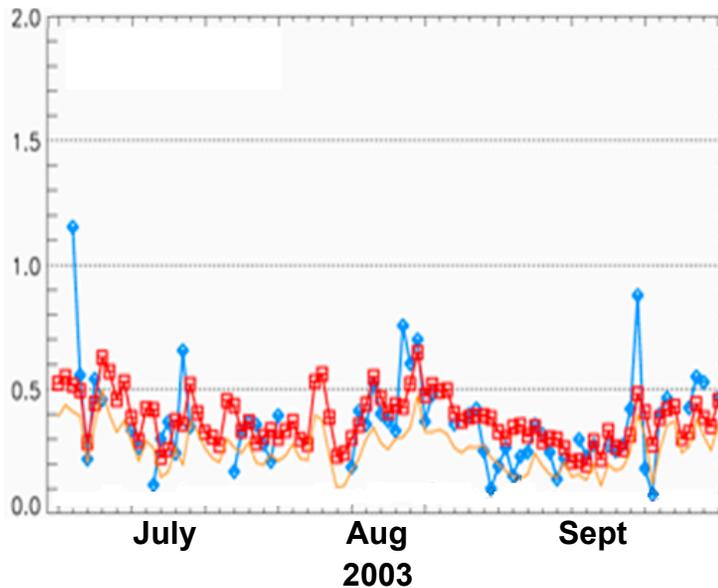
Site dominated by biomass burning  
Alta Floresta, Brazil

Without  
assimilation of  
aerosol data



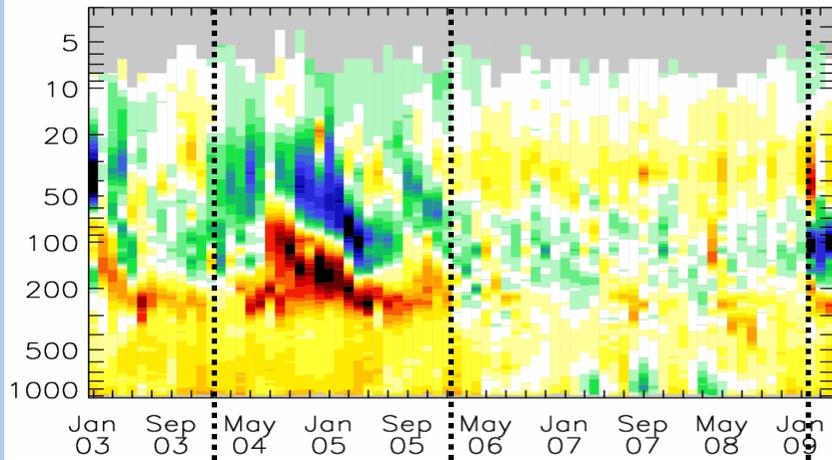
Aerosol  
Optical Depth at  
550nm

With  
assimilation of  
MODIS AOD

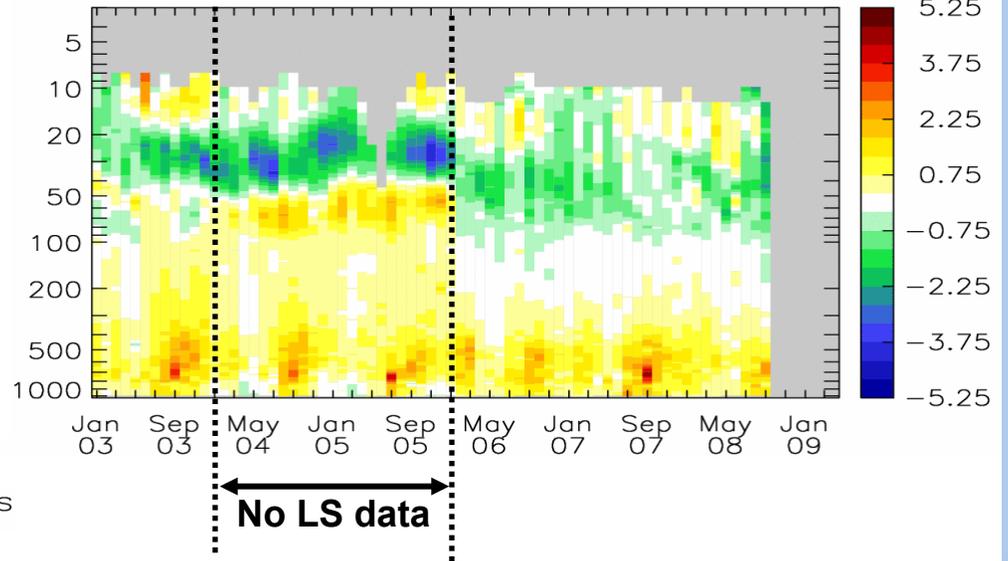


# Comparison of GEMS ozone reanalysis and ozonesonde data

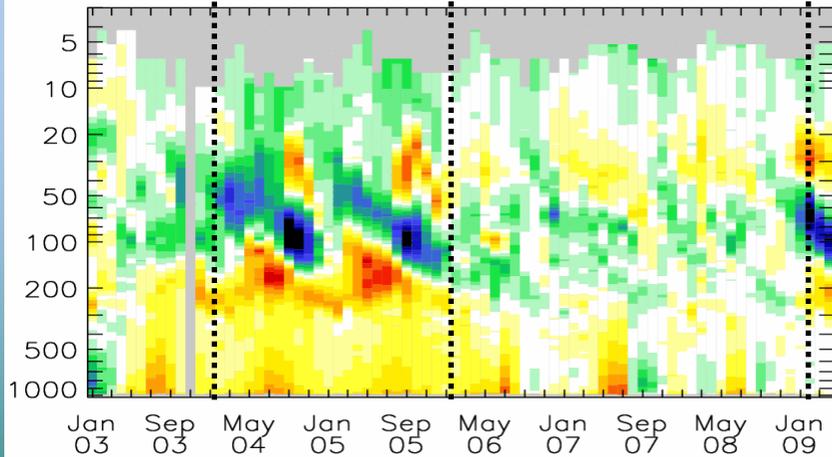
Monthly mean sonde-analysis (f026) profiles for G03 (mPa) over Ny-Ålesund



Monthly mean sonde-analysis (f026) profiles for G03 (mPa) over Ascension\_Island



Monthly mean sonde-analysis (f026) profiles for G03 (mPa) over Neumayer



**Limb-sounding data assimilated in 2003 (MIPAS) and 2006-2008 (MLS)**

**These data, especially MLS, are clearly beneficial**

**OMI data are used from July 2007**

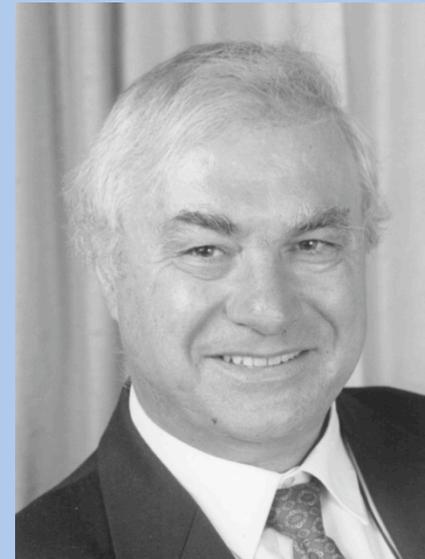
## The next two years – towards full operations

- **Consolidate and improve analysis and forecasting systems**
  - establish basic operational processes for near-real-time running
  - increase horizontal resolution to 80 km global, 25 km or less regional
  - refine other aspects of the analysis and forecasting systems
- **Monitor the quality of products on a systematic basis**
- **Supplement migrated production lines with new services**
- **Liaise with agencies to obtain the observations we need**
- **Liaise with users to supply the products they need**
- **Establish funding and governance for full operations from 2012**

# Acknowledgments

## **GEMS/MACC team at ECMWF**

Anna Agusti-Panareda, Angela Benedetti,  
Richard Engelen, Johannes Flemming,  
Antje Inness, Luke Jones,  
Johannes Kaiser, Jean-Jacques Morcrette,  
Miha Razinger, Martin Suttie



Tony  
Hollingsworth  
(1943-2007)

## **MACC Management Board members from partner organizations**

Olivier Boucher, Met Office  
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Claire Granier, Service d'Aéronomie  
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Henk Eskes, KNMI  
Thomas Holzer-Popp, DLR  
Vincent-Henri Peuch, Météo-France  
Martin Schultz, FZ Jülich

**and all other team members** (I. Chiapello, Y. Derimian, J. Gulliver, ...)